Improving the noise model for AIUB monthly gravity field solutions

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INTRODUCTION

The quality of monthly gravity fields from GRACE data is limited by noise of the onboard instruments (GPS, K-Band, accelerometer and star cameras) and deficiencies in the background models (third bodies, tides, de-aliasing: AOD1B).

The Celestial Mechanics Approach (CMA) absorbs the background model deficiencies by constrained piecewise constant stochastic accelerations over 15 minute intervals, estimated together with all other orbit parameters and the gravity field coefficients. An analysis of the quality of the resulting monthly gravity models reveals that especially during times of high solar activity this measure is not sufficient to generate high quality gravity field solutions.

This poster analyzes the carrier phase residuals of the kinematic orbit determination and the K-Band range-rate residuals of the combined orbit determination using the previously determined kinematic positions and the Level-1b K-Band range-rate data as observations.

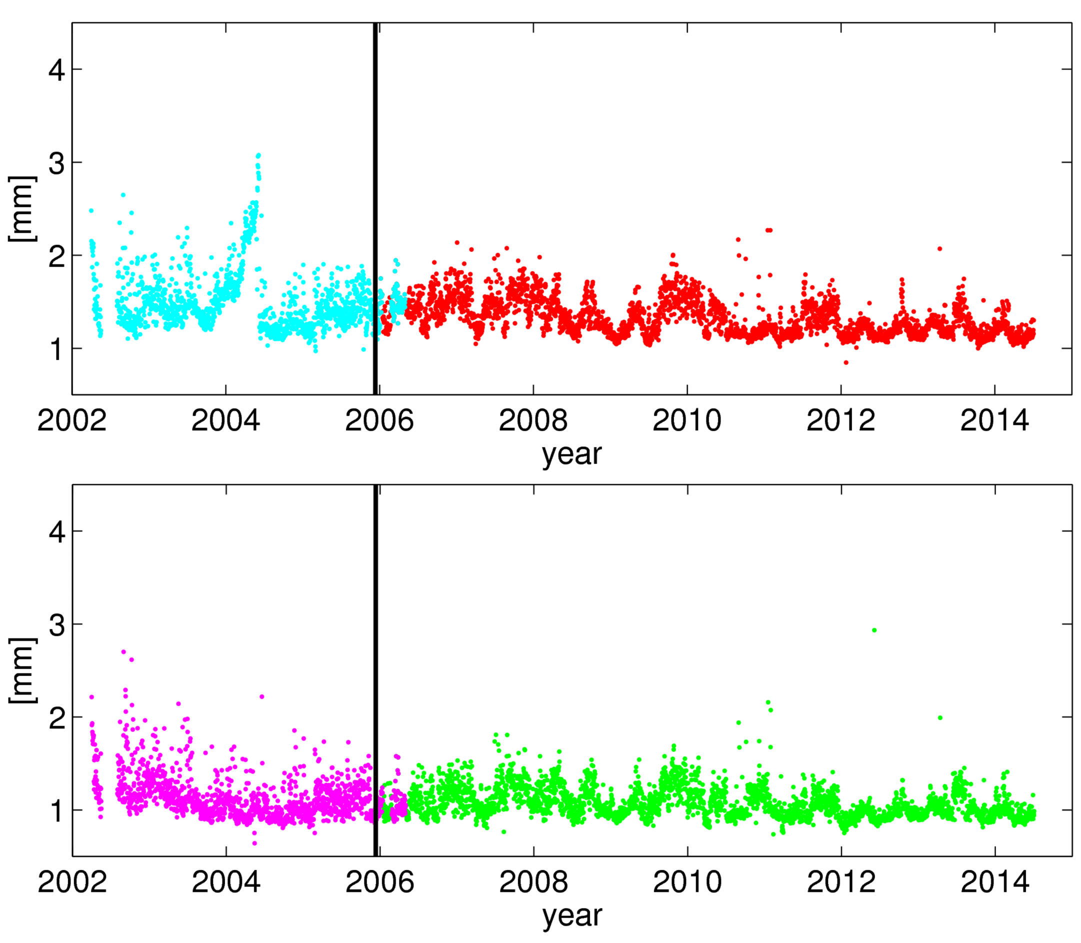

Fig. 1a,b: Daily RMS of ionosphere free phase residuals of GRACE A (top) and B (bottom). Systematics were already reduced by empirical Phase Center Variation (PCV) maps prior to (light blue/violet) and after (red/green) turning on the occultation antenna. The black line marks the satellite swap in December 2005.

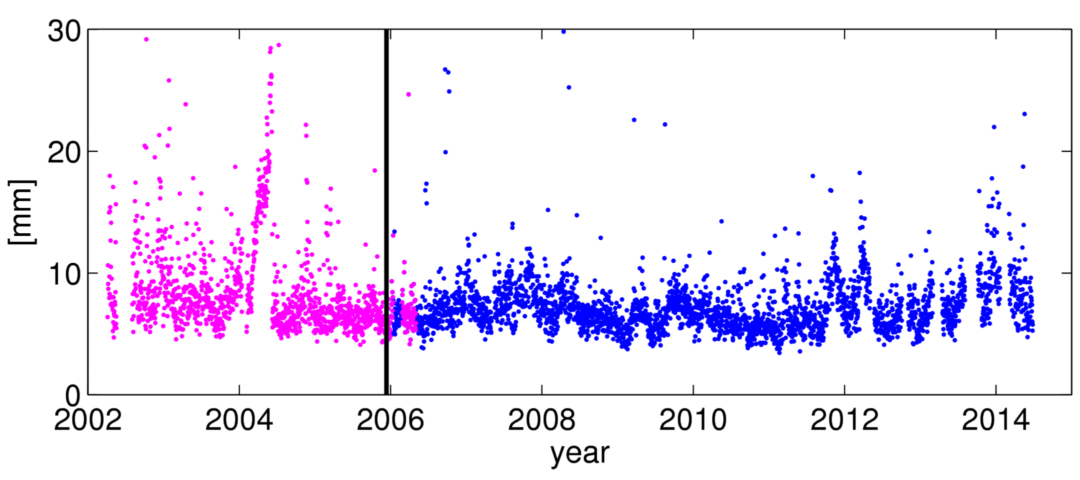

Fig. 2: Daily RMS of K-Band validation of reduced dynamic orbits. The systematics visible in Fig. 1 are confirmed.

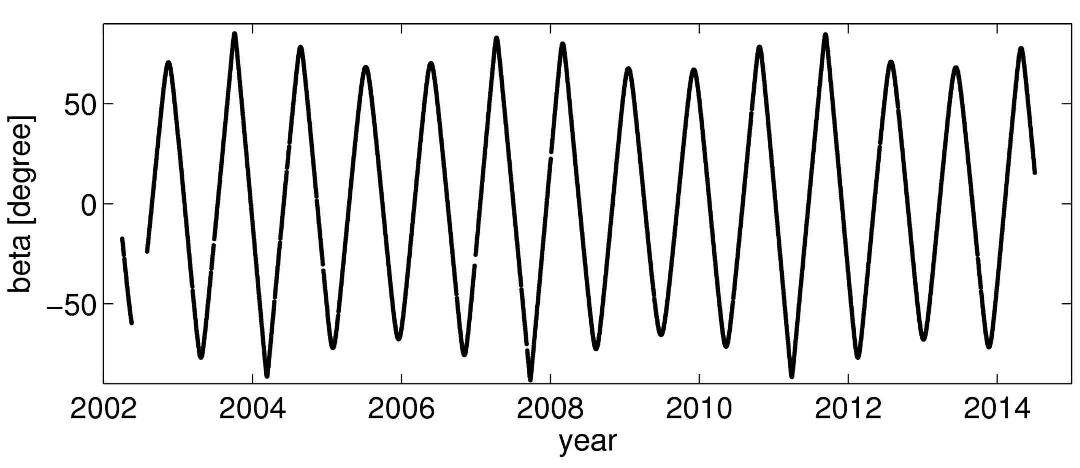

Fig. 3: Angle β between orbital plane of GRACE A and direction to sun. The noise of the kinematic orbits shows a dependency on β that is aggravated during times of high solar activity.

KINEMATIC ORBITS

The kinematic orbits of GRACE A and B are derived by a zero-difference Precise Point Positioning (PPP) and are later used as pseudo-observations for the determination of the gravity field coefficients. Systematic errors like multipath and cross-talk with the occultation antenna are modeled by empirical phase center variations.

From approx. doy 60-160 in 2004 a degradation of the kin. orbits of GRACE A can be observed (Figs. 1a and 2). In the antenna fixed systems the GPS phase residuals show a systematic behavior. Therefore we propose to apply specific PCV corrections for this period (Fig. 4).

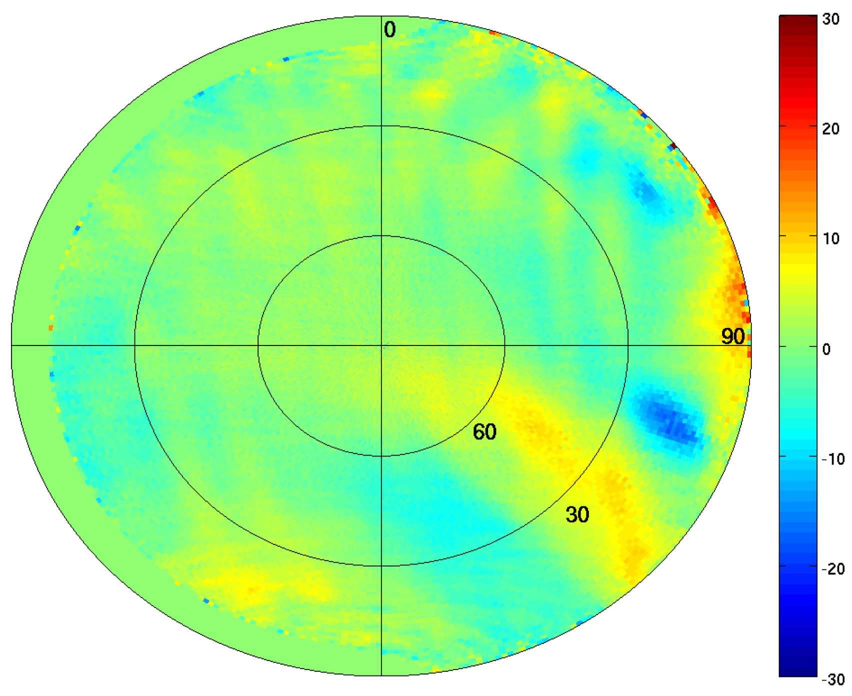

Fig. 4: GPS L3 phase residuals of doy 60-159, 2004 in the antenna fixed system (flight direction is left, antenna zenith in middle of plot).

KINEMATIC POSITON RESIDUALS

Orbit parameters and stochastic accelerations were determined in a fit of daily arcs to the kinematic orbits. The static gravity field GOCO03Sp (derived from 7 years of GRACE + 1 year of GOCE data) was used up to degree 120 in the force model. As opposed to Figs 1a,b the resulting residuals reflect observation noise as well as model errors (Figs. 5a,b). Note that the constraints on the stochastic accelerations were kept constant over the whole time period.

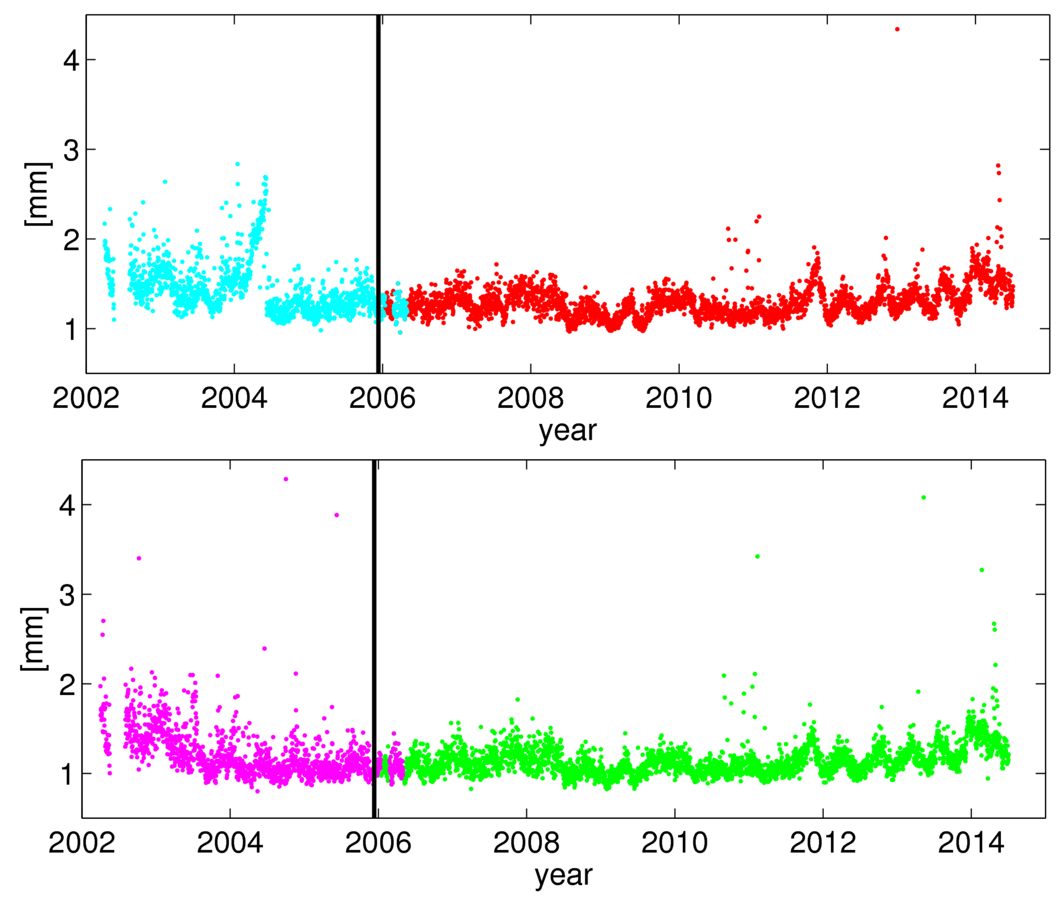

Fig. 5a,b: Daily RMS of the fit of reduced dynamic to kinematic orbits.(top: GRACE A, bottom: GRACE B). Additionally to the noise of the kinematic orbits a slight increase before 2004 and after 2012 is visible. It is probably related to high ionosphere activity in these periods and might indicate that the spacing and constraining of the stochastic accelerations needs to be adjusted.

RANGE-RATE RESIDUALS

As soon as K-Band range-rate observations are taken into account, the relative accuracy in along-track between the resulting reduced dynamic orbits of GRACE A and B is dominated by the K-Band accuracy. The range-rate residuals (Fig. 6) show a clear dependency on the inter-satellite distance (Fig. 7). A noise increase before 2004 and after 2012 hints at an impact of the high solar/ionosphere activity. The general increase of noise during the mission may also be due to inadequate parametrization at low satellite elevation (Fig. 8).

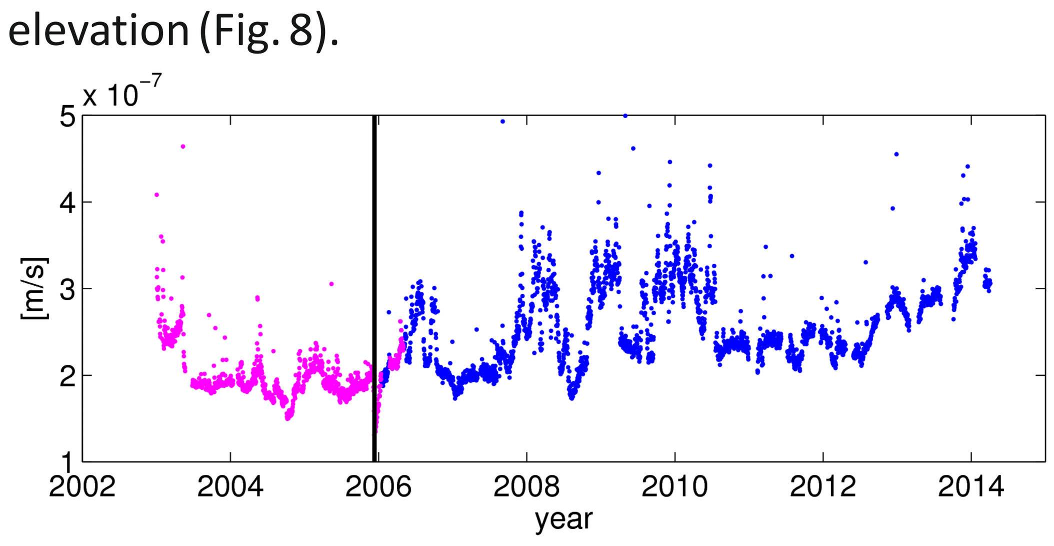

Fig. 6: K-Band range-rate residuals (the black line indicates the satellite swap; violet dots prior to turning on the occultation antenna).

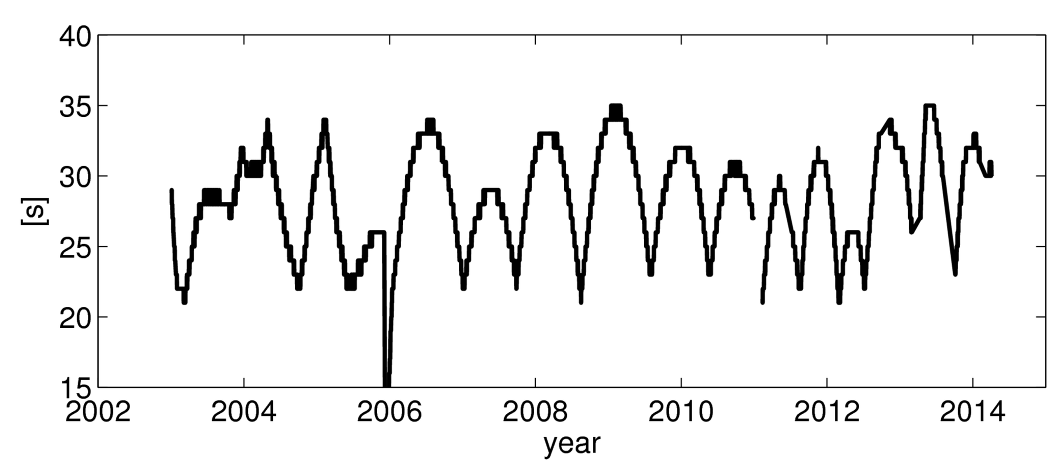

Fig. 7: Inter-satellite distance in terms of travel time of the trailing satellite.

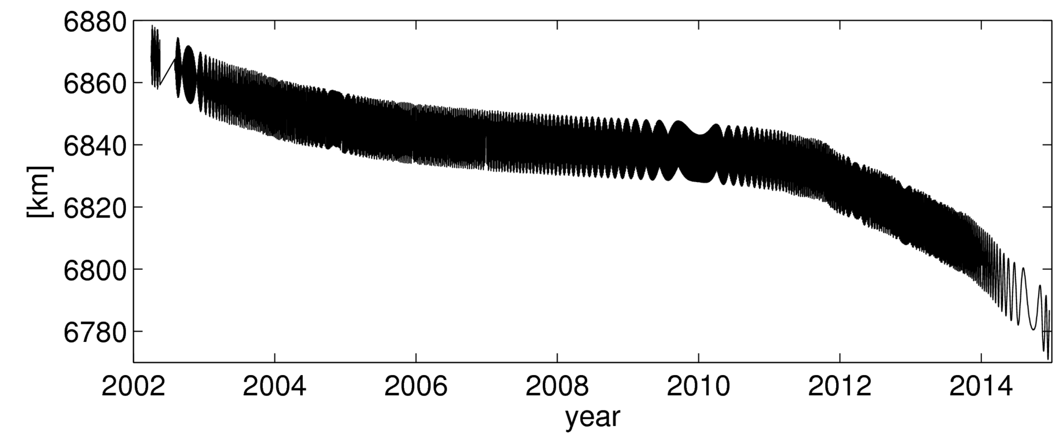

Fig. 8: Evolution of osculating semi-major axis of GRACE A orbits during the mission. The strong decline after 2011 corresponds to a period of increased solar activity.

RELATIVE WEIGHTING GPS / KRR

The relative weight of the kinematic orbits in the CMA so far was set to a constant 1e-10 (determined empirically). A observation dependant weighting could be derived from the ratio RMS^2_{GPS} / RMS^2_{KRR}. But the resulting daily weights are two orders of magnitude larger (Fig. 9) and the resulting monthly solutions strongly degraded. A empirical factor of about 1/300 solves the problem.

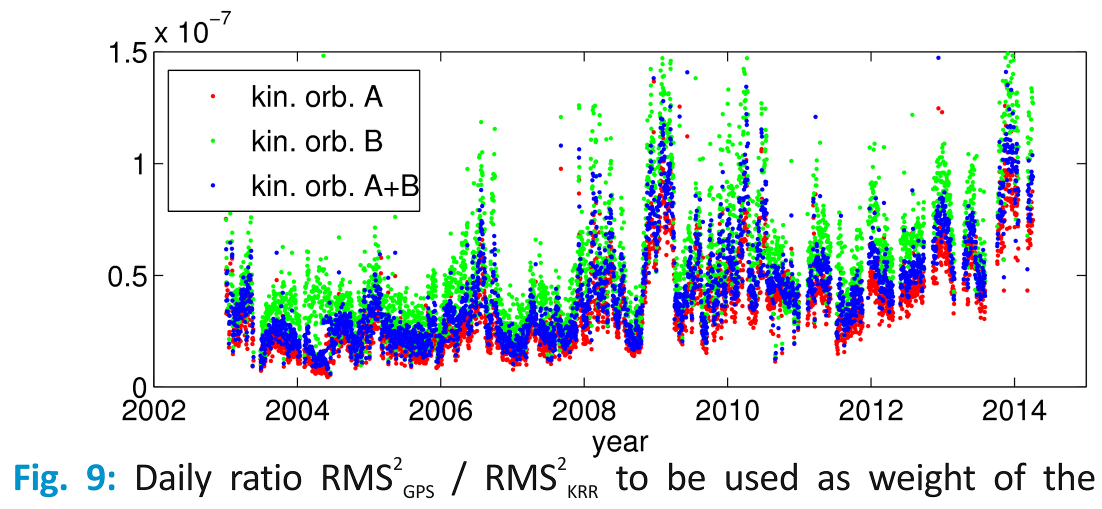

Fig. 9: Daily ratio RMS^2_{GPS} / RMS^2_{KRR} to be used as weight of the kinematic orbits relative to the K-Band range-rates.

NOISE IN MONHTLY GRAVITY FIELDS

The noise of the monthly solutions can be assessed by the standard deviation of the variability over the oceans (weighted by the cosine of the latitude). It shows a notable correlation with solar activity (Fig. 10) that can be significantly decreased by the estimation of daily accelerometer scale factors in along-track direction (Fig. 11). Especially C_{20} profits from the estimation of accelerometer scales (not shown).

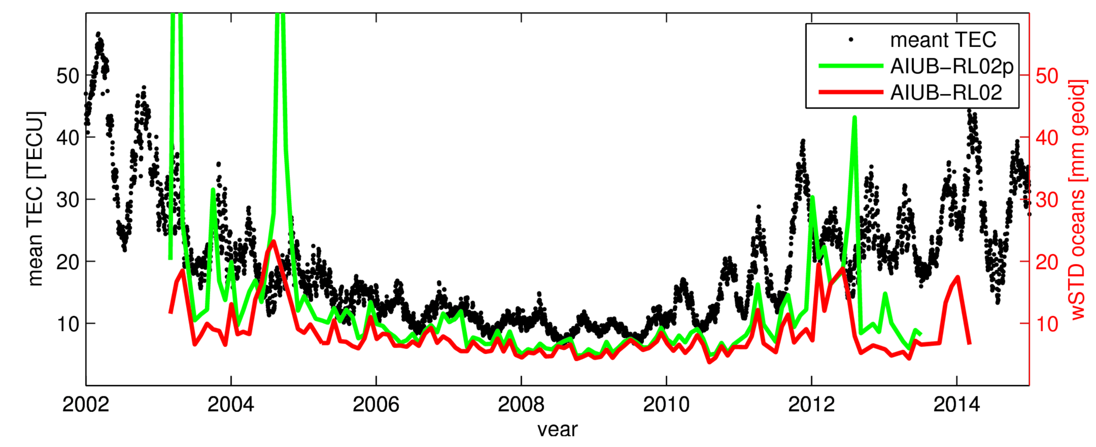

Fig. 10: Daily mean TEC and weighted standard deviations of monthly gravity fields estimated without (AIUB-RL02p: green) and together with (AIUB-RL02: red) daily accelerometer scale factors.

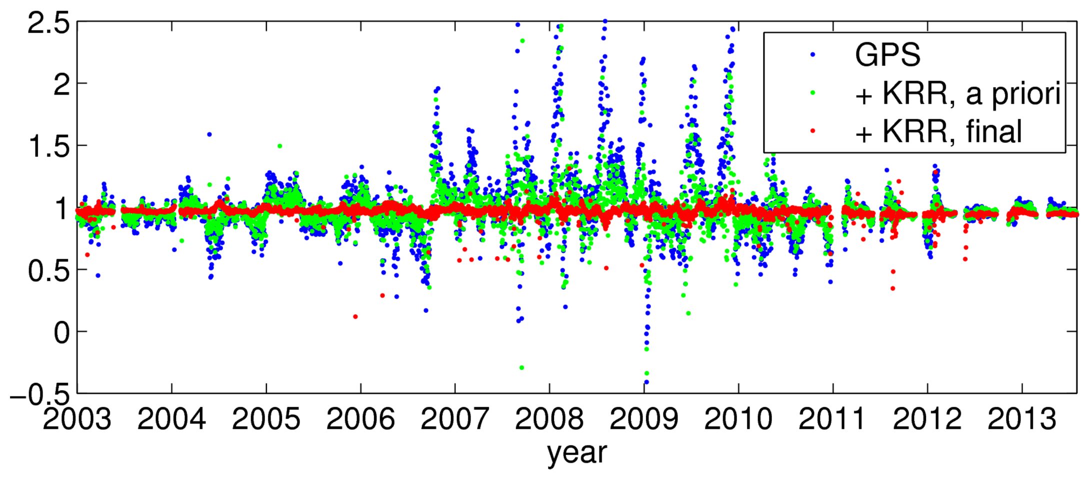

Fig. 11: Daily accelerometer scale factors for GRACE A (very similar results are obtained for GRACE B) show a scatter that is inversely proportional to solar/ionosphere activity. In the final results (red) the K-Band range-rate observations are weighted 280 times stronger than for the a priori orbits (green).

CONCLUSIONS

The fact that we have to down-weight GPS indicates some model deficiencies that lead to conflicts between GPS and K-Band. Before more advanced techniques for observation dependent weighting like variance component estimation can be applied, these model deficiencies have to be resolved. We assume that we either have to decouple GPS and K-Band by

- the introduction of empirical K-Band parameters or
- empirical covariances that are derived from the K-Band range-rate residuals.

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